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# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Docket No. 238/272		Type a plus sign (+) inside this box → +	
INVENTOR(S)/APPLICANT(S)			
LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
GIVON	MENI		ISRAEL
Additional inventors are being named on the separately numbered sheets attached hereto.			
TITLE OF THE INVENTION (280 characters max)			
AUTOMATED ASSESSMENT OF PERSONAL FINANCIAL RISK TOLERANCE			
CORRESPONDENCE ADDRESS (including country if not United States)			
Mark A. Catan, Esq. LYON & LYON LLP 633 W. Fifth Street, Suite 4700 Los Angeles, CA 90071-2066			
ENCLOSED APPLICATION PARTS (check all that apply)			
<input checked="" type="checkbox"/> Specification      Number of Pages <u>22</u> <input type="checkbox"/> Small Entity Statement			
<input checked="" type="checkbox"/> Drawing(s) Number of Sheets <u>11</u> <input type="checkbox"/> Other (specify) _____			
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)			
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.			
<input checked="" type="checkbox"/> No.			
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Respectfully submitted,

SIGNATURE Mark A. Catan Date: December 15, 1998

TYPED or PRINTED NAME MARK A. CATAN REG. NO. 38,720

TELEPHONE (914) 681-8851 Docket No. 238/272

## USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C., 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS.

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## A Primary Metal-Air Battery for High Current Portable Electronic Devices

### Background

The present invention relates to batteries and more particularly to metal-air  
5 batteries for portable electronic devices that require high current and high capacity.

Most high-drain portable electronic appliances are powered by secondary  
(otherwise known as rechargeable) batteries. Examples of such high-drain devices  
are cellular telephones, notebook computers, camcorders, and cordless hand-tools.  
The reason primary batteries are unattractive is that the longevity of typical primary  
10 (or disposable batteries) is so low, and the cost and weight so high, that operation  
would prove too costly to most consumers. For example, a cellular telephone with  
alkaline batteries, would last about as long as a single charge of a nickel-metal-  
hydride battery. The cost, however, would be on the order of several dollars.

However, new battery technologies have emerged that have, in principle at  
15 least, the ability to offer sufficient energy and power with sufficiently low cost to  
power high-drain appliances. One such technology is zinc-air. In zinc-air batteries,  
one of the electrodes of the battery is supplied by ambient oxygen which means  
that the battery has to carry only one consumable electrode. This magnifies the  
capacity tremendously. Unfortunately, this intrinsic benefit is attended by some  
20 troublesome requirements that make applying zinc-air batteries very difficult.

For one thing, air must be supplied to the battery. This creates some obvious  
design problems for a hand-held consumer appliance. Another problem is the fact  
that, since air must enter the battery, water vapor can leave the battery. Thus, zinc-

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air batteries are susceptible to desiccation in low humidity environments, potentially destroying their ability to function.

Another problem is that zinc-air batteries, while providing high energy density for the reason mentioned previously (only one electrode is consumed), are notoriously low on power. To provide high power, large amounts of air must be supplied. But small portable appliances do not provide a great deal of surface area for air access. In active air management systems, this is not a serious problem since large volumes of air can be pumped through a small opening. But active air management requires the expense and bulk of an air pump which is difficult to fit into the cost constraints of a disposable battery. With passive air management, such as in a hearing aid, taking a typical zinc-air cell such as a hearing aid battery, it would take a total surface area of on the order of 200 cm<sup>2</sup> to provide sufficient power to operate a typical digital telephone.

One prior art reference published on the world wide web shows a cellular telephone with a battery pack, but it shows no indication

Still another problem with zinc-air batteries is the fact that, as they discharge, the conversion of zinc to zinc oxide causes the internal volume of a battery to increase. This expansion must be accommodated by the battery. Zinc-air button cells can tolerate this expansion by providing internal space and high strength owing to the structural integrity inherent in their tiny disc-shaped designs. But larger cells, to accommodate such expansion, might be subject to tremendous forces, which would have to be accommodated by strong and heavy casing. Alternatively, as in button cell design, space could be left in the casing to allow for

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expansion, but this wastes volume and destroys the energy-density advantages offered by zinc-air technology. In addition, hydrogen gas is generated by the oxidation of zinc and this can be another source of expansion of a battery. Any attempt to scale up the design of a button cell would require a proportionately  
5 scaled-up material strength (metal thickness). To obtain higher voltages than about 1 volt, multiple cells are required. Fitting disk-shaped cells into a single package, however, leaves a great deal of wasted space between cells.

In some battery applications, the high power requirement is intermittent. For example, in digital pagers and cell phones, the power requirement is cyclic. in  
10 such an application, a zinc-air battery may be able to handle the average load, but not the current peaks. One proposal for dealing with this problem is to employ as a secondary power source, a capacitor that is charged by the main battery between pulses. When the current demand is lowered, the main battery charges the capacitor. When the current demand rises above a threshold, the recharged  
15 capacitor helps the main battery satisfy the demand. Among the problems with this solution are the cost, bulk, and weight of the electrolytic capacitor (on the order of 100 milliFarads up to a few Farads) required to satisfy the periodic demand, the fact that a capacitor mounted in parallel with the main battery would tend to dissipate energy from the main battery, and other problems. This latter problem  
20 does not necessarily make the idea inappropriate in all contexts, but it limits its applicability.

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## Description of the Invention

A compact long-life battery pack for portable appliances, for example, a cell telephone, provides for the unique demands of metal-air battery technology.

Referring to Fig. 1A, in an exemplary embodiment, multiple prismatic  
5 battery cells are arranged in a plastic casing and supported in such a way as to form a contiguous internal space or plenum in communication with ambient air. The casing is liberally supplied with openings such that air can flow freely due to local pressure gradients induced by local heating of an attached appliance, by diffusion due to differences in partial pressure of oxygen and nitrogen, or by ambient  
10 pressure fluctuations. Each cell has an array of air holes, such as used in zinc-air button cells, in such number and size as to allow oxygen to be supplied to a cathode inside the cell. The air holes of each cell face the plenum. The spacing of the cells provides for their expansion. The casing of each cell is strong enough to insure that any hydrogen gas generated in the cell due to corrosion of the zinc will be forced  
15 out rather than causing expansion of the casing. However, the casing is flexible enough to permit expansion due to the more unyielding force of zinc expansion.

The air holes are sized and populated to insure that the cathode, under high current load, is not starved for oxygen, which would cause the voltage to drop. For ease of manufacturing, it has been found desirable to employ holes of around 0.4 to  
20 0.5 mm in diameter because such holes can be punched conveniently in cells of 0.1-0.4 mm casing wall thickness and provide good air access while, at the same time, limiting unnecessary desiccation. The population and spacing are designed to limit excessive desiccation according to any desired technique, the preferred one of

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which is to determine experimentally the area of the cathode supplied by each hole. This is done by bringing a limited number of holes, say two, closer and closer from a remote separation until the total current generated by the cell starts to drop off significantly. This indicates the point where the area supplied by the holes begins to overlap significantly. A more dense spacing simply provides area for evaporation without contributing substantially to oxygen supply to the cathode.

Each of the cells of the battery pack contains an air cathode and a zinc anode. The cathode lies adjacent a cathode side of the cell casing separated from that side by a diffuser. The diffuser distributes air from holes in the cathode side of the cell across the surface of the cathode and keeps the cathode a specified distance, equal to the diffuser's thickness, from the cathode side of the cell. The holes in the cathode side of the cell are uniformly distributed across the primary plane of the cathode side of the cell.

The cell pack casing is scattered with small holes. Preferably these holes are of such a diameter and the casing of such material (hydrophobic) that water splashing onto the casing beads up and is substantially prevented from dripping into the casing. In an alternative embodiment, the casing is made of a porous plastic such as Porex ®. Porex Technologies, the manufacturer, make molded parts of porous plastic from hydrophobic materials to resist water-entry through spillage. For example, PTFE or Nylon 6.

Referring to Fig. 1A, in an embodiment, developed for a popular cell phone, has six cells. The cathode side of each cell faces away from the telephone toward the back side of the cell pack. Thus, the holes of all the cells face in the same

direction forming two parallel layers defining a plenum between them. Another plenum is defined between the outermost layer of cells and the outermost major plane of casing. The latter plenum is very thin; on the order of a millimeter and less. Since the holes are so plentiful for the outside layer of cells, a large plenum is  
5 not required to insure good oxygen access. The plenum between the two layers of cells is 4-6 mm thick. A thicker plenum is desirable here to insure that oxygen does not have a very long diffusion path. Various mechanisms involved with plenums, such as the buffering effect, the lower laminar flow resistance to air flow, etc., are responsible for this effect and are not discussed here.

10 Referring to Fig. 2, to support the cells in the arrangement shown requires some sort of structure that is compatible with low cost automated production. One embodiment of a low cost support structure, or "spacer," for the cells is a spacer design that has a pair of partitioned trays joined by a living hinge integrally formed in the tray. Each tray contains a respective partitioned area for each cell. Integrally  
15 formed in the bottom of each tray are standoffs that insure the separation for the plenum between the layers of cells. The recesses of each tray is closed and can accommodate an absorbent material to soak up any leaking KOH. The partitioning between cells also helps to prevent shorting through leaking KOH and to hold each cell in a precise placement separated from the other cells by a precise distance. The  
20 shapes of the partitioned areas for each cell may be made to cause the cell to snap into place. Alternatively cells may be adhered to the back plane of each partitioned area. The partitioned areas may be closed or open.

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Referring to Fig. 3, another support or spacer design is shown below. This design would best be made of injection-molded plastic with precisely-defined skirts for each cell. Each support may accommodate a given number of cells. Each support may have standoffs to separate the layers of cells insuring the minimum  
5 spacing required. Each support has snap trays to hold the cells in place. The back of the casing is molded to hold the cells in the lower layer in place as shown.

Referring to Fig. 4, still another support for the cells is formed by the casing itself. The two-part casing has a skirt portion with molded bumps positioned such that the cells snap into place from either direction. A cover is then snapped onto the  
10 skirt to form the completed housing. Another cover may be placed opposite the first to fully enclose the cell chamber. Note that, holes may be formed in the recess that defines the supports for the cells so that the holes cannot be covered by a user's hand causing suffocation of the cells. That is, the channel formed in the skirt portion of the casing cannot be blocked by a generally planar surface such as a  
15 hand holding the phone. As mentioned, the cells may be oriented to face the main plenum between the rows or to face in the same direction away from the telephone. The latter may be preferable in the event that water or other liquids are spilled on the telephone.

Referring to Fig. 5, air may be managed by passive or active mechanisms.  
20 A set of semi-active mechanisms has particular advantages of low cost and ergonomic benefits, for example applied to a cell phone. In one, the casing opens as a clam shell when the telephone is in use. A motor opens the casing in response to a control signal from a controller that detects a high current demand. When the

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current demand falls off, the casing is closed by the motor. In one embodiment, a clam-shell cover opens to let air into a compartment containing battery cells. The open position of the cover allows a large amount of air to circulate freely about the cells and also provides a more ergonomic.

- 5           A shutter mechanism can be integrated into the casing design. Such shutters may be operated manually or by a motor. In cell phones, for a user to tolerate being required to manually operate such a shutter mechanism, an incentive may be provided to coincide with the shutter operation according to the following design criteria: (1) the open-shutter configuration coincides with enhanced ergonomic
- 10 configuration, preferably less compact than the closed shutter configuration, suitable for holding in the talking position of the cellular phone; (2) the closed shutter configuration coincides with a compact configuration; (3) the open-shutter configuration is achieved automatically by drawing a substantial current from the battery; (4) the open-shutter configuration is achieved by means of a spring motor
- 15 and is instantiated by a simple release mechanism so that little power is required; (5) the spring driving the mechanism to the open-shutter configuration is compressed by closing to the closed shutter position; (6) the closed shutter position provides very low internal air volume so that the trapped air volume is quickly saturated to insure that moisture exchange between the cathode and the ambient air
- 20 is quickly cut down, which in turn insures that continued evaporation after the shutter is closed is as brief as possible. In the embodiment of Fig. 5 the cells are pressed against a piece of polymer foam to partially seal them from the air when the clam shell is closed. The foam is supported on resilient strands so that it is held

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in the middle of the plenum space when the clam shell casing opens. The configuration is very compact because the plenum is reduced to almost zero when the casing is "closed."

It has been found that low temperature operation is substantially  
5 ameliorated by the application of external pressure to the contents of the cells. Pressed cells were found to provide substantially higher voltage over their discharge history than unpressed cells. Pressures in the range of 1 psi to 25 psi were used. In addition, pressure was found to reduce the voltage delay phenomenon. It has also been found that pressure positively impacts the performance of the zinc-air  
10 cells in low humidity environments. Pressure may be applied by wrapping the cell with external strapping or external springs (Fig. 8), by closing the cell casing while pressure is applied so that the cell casing itself applies pressure to the cell's contents, or by any other suitable means. Still another technique for generating the desired pressure in the cell is to indent the casing after formation. To insure that  
15 pressure does not rise above a certain level, say 5 psi, the casing may be formed in such a way as to yield at a certain pressure, allowing continued expansion. Such expansion occurs as zinc is replaced by zinc oxide as the cell is discharged.

Another mechanism for improving low temperature performance of zinc-air cells is to add a low-viscosity diluent to the zinc electrolyte mixture. For example,  
20 isopropanol, isobutanol, or secbutanal could be used. Still another mechanism for increasing low temperature performance is to add alumina,  $Al_2O_3$ , to the anode zinc/electrolyte mixture. Concentrations of 5% w/w zinc of the low viscosity diluent have been found effective to increase the discharge voltage by 60 mV and

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concentrations of alumina of 1% w/w have been found to increase capacity by about 10%.

Another problem in zinc-air batteries is the corrosion of zinc. It has been found that the addition of polyethylene glycol (PEG), to the zinc/electrolyte mixture, in amounts of 1-10% w/w zinc inhibit corrosion of zinc measurably. PEG of various molecular weights may be used. Mol. wts. of 600, 1500, 10,000 were tested and the latter found less effective than the former. It was found that concentrations in the upper end of the specified range reduced capacity substantially; on the order of 15-20%. Alternatively, oleate oil may be used.

10 The cells may be formed of triclad metal of nickel, stainless steel, and copper (in that order) with the zinc anode facing the copper. Preferably, the surface of the copper is plated with indium to reduce corrosion of the zinc.

To reach the high current requirements of many cellular telephone applications, very high zinc surface areas are needed. Electrolytic zinc (zinc formed electrolytically with very high surface areas - also a known process) is known for providing much higher surface to mass ratios than thermal zinc (zinc formed by atomizing molten zinc in a well known process). Because of the process of forming electrolytic zinc, it is difficult to form particles containing other corrosion-inhibiting metals alloyed with the zinc. However, thermal alloyed zinc is not a problem. The zinc used in the anode may include a mixture of thermal zinc with electrolytic zinc to provide some of the corrosion-inhibiting benefits of thermal zinc with the high surface area of electrolytic zinc. Mixtures of approximately 10% to 50% electrolytic zinc may be used. The higher end of the range provides an

ability to form a biscuit out of the zinc, potentially eliminating the need for a gelling agent traditionally used in zinc-alkaline batteries. The biscuit can be formed by pressing the mixture of electrolytic zinc together with the thermally-formed powdered zinc. The dendritic structure of the electrolytic zinc allows the electrolytic  
5 zinc to form tangles which cause the pressed mixture to form a porous rigid structure. The biscuit structure can facilitate manufacturing by avoiding the need for settling time that would be for the zinc bolus to spread into the prismatic casing.

Another important feature to provide for providing high current capability in zinc-air batteries is to insure that the cathode is fully saturated. The cathode  
10 tends to dry out as a result of desiccation and as a result of the waters of hydration drawn away by zinc oxide as it forms during discharge of the cell. The addition of hydrophilic agents to the cathode, for example, cellulosic materials such as Natrosol ® 250H NF hydroxyethylcellulose (HEC) may be added to the cathode material. As moisture leaves the cathode during discharge, the HEC holds onto it  
15 and makes it available in the cathode despite progressive drying of the anode. Similar material has been used as a layer, but the incorporation of the material in finely divided form inside the cathode active layer helps to insure the moisture is held where it is needed.

It has been found that the concentration of zinc in the anode may be lowered  
20 to levels below those normally used in zinc air batteries for better long term performance. The w/w percent of zinc in the anode may be only about 60% instead of 70-80% as employed in the prior art. This helps to insure maximum utilization of zinc by helping to prevent zinc dryout and the attendant drop in power capacity.

Referring to Fig. 6, in the embodiment shown above, there is only one cathode and only one side of the cell contains holes to supply air to this single cathode. In an alternative embodiment, two cathodes, each lying adjacent one side of the cell, are provided. Each major plane of the casing, in this latter embodiment, is supplied with a distribution of holes to feed a respective cathode. In this latter embodiment, the cathode current collectors may be supplied directly connected to the entire casing. The anode current collector may be fed through the casing and insulated from the casing by an insulating grommet.

Current collectors in the anode and cathode are metallic screens embedded in the anode and cathode materials respectively. Preferably, each is a piece of expanded metal screen and preferably, the cathode screen is prepainted with a conductive paint before being incorporated in the cathode. Preferably a paint of TFE, water, and carbon in emulsion is used.

An active layer of the cathode is formed by roll-forming activated carbon, a catalyst, preferably  $\text{MnO}_4$  or  $\text{MnO}_2$ , and TFE into a sheet. The resulting sheet is pressed together with the cathode screen, preferably of nickel. Two sheets of Teflon, one compressed and other uncompressed (.076 mm and .10 mm, respectively) are laminated together and the resulting laminate, laminated to the active layer with the uncompressed sheet adjacent the anode-facing surface of the active layer. This Teflon laminate allows air to diffuse into the cathode while preventing moisture from leaking out. A Teflon separator sheet is laminated to the zinc-side of the cathode active layer to prevent zinc particles from contacting the cathode. The separator is chosen to allow ready diffusion of KOH into the cathode.

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5 The dimensions of the active layer and the separator layers are 0.4 mm and 0.025 mm, respectively. The final pressure used to laminate all the layers together, preferably, is not too high. A pressure of 45 psi drive side has been found to produce a cathode that is substantially lower in density than prior art cathodes which has been found to permit higher power output over the discharge history of the cell. The carbon used in the active layer is preferably Black Pearls 2000 (R) available from Calgon Carbon in Pennsylvania. The diffuser may also be laminated to the resulting cathode laminate to produce a single sheet element to reduce the number of parts in the final cell assembly process.

10 The low pressure formation and other aspects of production discussed below have been found to provide a cathode with a limiting current density of over 500mA/cm<sup>2</sup> whereas prior art cathodes are characterized by much lower limiting current densities, typically of around 100mA/cm<sup>2</sup>. The following production steps were followed to produce the cathode.

15 Example 1: Preparation of base material

240 gr. of MnO<sub>2</sub> powder (grade HPX from Chemetals, USA) is ground finely in a ball mill for 24 hours (left out: wet milling). The MnO<sub>2</sub> is then poured into 4 liters of DI water (really 9 liters) and heated up to 85°C. Add 400 gr. of ADP carbon (supplied by Chemviron, Belgium) while stirring. Then add 288cc of T-30 PTFE suspension (supplied by DuPont). Continue stirring for one hours, then filter and dry at 120°C for 5 hours (left out: cooled down during this hour ~50°C, from Charlie. Chop the active mass in a hammer mill.

Example 2: Addition of the Liquid Reservoir

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Slowly add 200g of the active mass made in example 1 to 5 litre of DI water stirred at 85°C. After all the carbon is in suspension, add 2 grams of Natrosol (grade 250MBR from Hercules). Continue stirring under heat until dry (left out: dried in oven when solution too viscous. Could put in "filter" which might be a good red herring, though not tested). Chop the active mass treated with the liquid reservoir in a hammer mill.

#### Example 3: Air Electrode manufacture

The active mass treated with the liquid reservoir from example 2 is spread evenly over a Nickel Mesh (40x40 0.005 Nickel from National Standard) (left out: cold bonded) and pressed at 400 kg/cm<sup>2</sup> to make an active layer of an air electrode. A porous Teflon sheet (left out: grade) is then pressed on one side of the active layer at 130 kg/cm<sup>2</sup> (mention pressures?).

#### Example 4: Cell manufacture

The air electrode from example 3 is then laminated with two separators. A microporous PP film (grade 3501 from Celgard) and a non-woven (grade 2704 from PG1, Chicopee). The air electrode and separator laminate is then crimped into a Zinc-Air cell of area 10cm<sup>2</sup> containing 3.1g Zinc and 2.4g 8M KOH solution, using techniques well known in the industry.

#### Testing Technique

The cell is stored in a 25-30%RH environment along with a control cell that does not contain the Liquid Reservoir. The cells are open to this environment without their tabs that normally prevent evaporation. After 7 days the cells are discharged using a GSM profile. This is a galvanostatic square wave profile

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consisting of 1.3A for 0.6msec and 0.08A for 4.0msec. This profile is one of the standard profiles used by mobile communication devices for communicating with ground stations. The discharge is for one hour (0.2Ah). After this the cells are returned to the low humidity environment. This discharge is repeated every 3-4  
5 days until the cells fail. This is defined as the high current voltage falling below 0.9V.

### Results

On the initial test after 7 days, both types of cells had a voltage above 0.9V. But when tested after 11 days in total in 25%RH, the cell without the liquid  
10 reservoir failed. The cell with the liquid reservoir continued to work for four subsequent tests totaling 25 days storage in 25%RH.

The separator layer may be formed of a layer of Veratech® adjacent the cathode active layer and a layer of polyvinyl alcohol. A 3-dimensional network adhesive may be soaked into the Veratech® layer which, when it dries, forms a  
15 porous 3-D network inside the Veratech® layer. If it were attempted to glue the Veratech to the cathode directly, the impermeable adhesive layer would substantially inhibit the flow of KOH. The porous network of adhesive in the porous Veratech® layer insures that KOH can freely pass and the PVA is essentially bonded to the cathode through the Veratech®-adhesive combination.

20 The cell casing, preferably, may be formed of metal or plastic. In either case, the cathode may be adhesed at its edge to the cell casing adjacent the cathode side of the cell. This adhesion encapsulates the cathode active layer and insures that

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zinc cannot migrate around the separation layer of the cathode to short out the cathode.

5 The separator layer mentioned above may be, for example Microporous hydrophobic polypropylene (PP) membranes or Celgard ®. In some applications, preferably, the separator pore size is chosen in the range of about 0.5 micron and above (up to 2 microns) instead of the more typical size range employed in battery applications with an average pore size of much less than 0.5 micron. It is believed that the larger pore size is sufficient to limit crystallization of zinc oxide in the separator layer while permitting greater wetting of the cathode active layer with

10 KOH solution. Another type of separator layer that may provide better cathode performance is microporous polyethylene whose hydrophylicity is enhanced by radiation grafting. Another candidate is Celgard chemically treated to enhance its hydrophylicity in a technique published recently. The modification of the Celgard was carried out in two stages: membranes hydroxylated by treatment with aqueous

15 potassium peroxydisulfate solution under a strong flow of nitrogen. then the hydroxylated membranes were subjected to grafting of acrylamide using ceric ammonium nitrate as an initiator. Subsequently, acrylamide grafted PP membranes were partially hydrolyzed to have carboxyl functional groups at the membrane surfaces.

([http://www.interscience.wiley.com/jpages/0021-](http://www.interscience.wiley.com/jpages/0021-8995/abs/v60n12p2087.html)

20 8995/abs/v60n12p2087.html.)

Battery cells may be formed of, preferably, metal or plastic. In either case, the casing is preferably made thin enough to yield under the pressure caused by zinc expansion rather than require a large air space as in zinc-air button cells. In

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plastic cells, it is preferably that no air space be used to maximize the quantity of zinc/electrolyte in the anode.

The metal cell may be formed as described in the pending application entitled "Plastic Prismatic Metal-Air Cells," (hereafter, the metal-cell application).

- 5 Instead of crimp-forming the metal casing, alternatively, the casing may be partially crimp-formed, relying not on the crimping forces to form a complete seal, but on tar coated elements. Thus, the grommet of the metal structure described in the metal-cell application may be coated with tar and the cathode portion of the metal casing slightly crimped over the anode cover. The tar fills in any gaps
- 10 between the grommet and the metal casing.

- To better distribute forces along the top cover of the metal anode cover, ridges may be formed in the flat portion of the casing anode cover to make the cover more rigid. The anode cover rim is preferably sloped so that any crimping forces cause the rim to push radially outwardly rather than radially inwardly. That
- 15 is, when a crimping tool forces the sides of the cathode portion of the cell casing inwardly to effect crimping, the forces exerted near the top of the anode cover tend to force the outer edge of the rim portion radially inwardly.

- The bend at the end of the anode cover serves to increase the area of contact between the grommet and the anode cover which helps to prevent leakage of
- 20 electrolyte. The increased area also distributes the crimping forces helping to avoid damage to the grommet. The recess 34 can be used to hold an absorbent material to absorb any leaking electrolyte. Also this recess 34 forms a channel that helps to make the anode cover more rigid. The bottom surface of the cathode portion of the

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cell casing is sloped below the bend so that the rim rides this slope outwardly when crimping forces are applied. This, together with the slope of the rim of the anode cover, helps to stretch the cathode and force the wire mesh into the cathode portion of the casing making good electrical contact.

- 5           The groove marked 54 in Fig. 6 of the metal-cell application, insures that the inside cell wall is vertical and flat helping to insure the edges of the cathode current collector make good contact with the cathode portion of the cell casing. This is insured because the inevitable curvature of the interior of the casing due to stamp-molding does not bend the cathode upwardly potentially driving the current collector away from the walls of the cathode portion of the cell casing. (In button cells, the interior of the casing is stamped with a sharp edged punch tool to make a sharp corner. The need to cut a sharp corner is avoided by the channel 54.
- 10

- The cathode portion of the cell casing must be crimped around the curved corner (that is, curved from the top view perspective) edges of the anode cover. This can cause corrugation of the inside of the edge. To avoid this, the cathode can be made from a very soft metal or annealed at the portions prone to corrugation. Also, the portions prone to corrugation may be cut back so that they do not reach in as far. This is effective since crimp over the (top view) curved portion does not need to be curved (side view) over the top of the anode cover to retain its position.
- 15
- 20       This can also be achieved by punching the cathode portion with a die that has raised portions at the corners pulling the corner edges down.

A plastic cell construction is described below. Cathode material as described above is cut into cell-sized portions. A punch is preferably used because

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of cost and speed, but punching should be done with the separator-side of the cathode facing down since, if the teflon layers face away from the punch stroke, the teflon may delaminate. The air-side (same as teflon side) of the cathode is primed adjacent the edge with a mixture of acrylic cement and chloroform. The primed edge covers just enough of the surface for bonding the cathode to the cell casing to seal off the volume between the casing holes and the cathode and thereby prevent leakage of electrolyte out of the cell. The primer coating forms a mechanical bond with the pores of the teflon to the primer coating allowing adhesion of the teflon to the cell casing. Therefore, the primer should preferably be forced into the pores and sufficient chloroform added to make the primer thin enough to work into these pores. Preferably a mixture of 10% w/w solids has been found to be effective. In high speed production, this may be done with an ultrasonic mixture feeder or screen printing. A second layer of primer may be added and is preferably added. The second layer may have 25% solids, which has been found effective. The need to work the material into pores during the application of the second layer is not as important since the first layer may seal most of the pores. It has been found that simple application of the second layer is effective.

A shelf portion of a casing of Noryl® Modified Polyphenylene Oxide and Polyphenylene Ether, the shelf portion being the part against which the cathode seals, is painted with model cement diluted with chloroform to soften the Noryl®. It has been found that Noryl® will crack if pure solvent is applied to soften it. After allowing about 1 hour at room temperature for the Noryl® to soften (or 1-2 minutes at 200F), a bead of 3M brand 2216 epoxy may be applied to the primed region of

the cathode. This is allowed to set for 2 hours, or 2-1/2 minutes at 200F. The epoxy sets to a caulk consistency. The diffuser, if not already laminated to the cathode, is glued to the cathode side of the cell casing. The cathode with the epoxy side facing the cathode portion of the cell casing is pressed against the shelf portion right over the diffuser. Preferably pressure is applied to the cathode and can to insure a good seal. This may remain in place for 12 hours or 10-15 minutes at 200F. Testing of the seal with water may be performed at this point.

A feed-through is installed in the casing/cathode combination to create a first electrical contact. This procedure and construction may be as described in copending application entitled Electrical Feed-Through for Metal-Air Battery Cell (inventor, Ronald Putt filed October 14, 1998).

A seal at the junction of the separator and the casing is next formed around the perimeter of the cathode. This seal may be formed of wood glue. A bead of wood glue or tar may be applied between the separator on the cathode and the wall of the casing to prevent zinc particles from migrating into the active layer of the cathode causing a short. Drying of wood glue takes about 1 hour. A foam space-filling ring may be inserted at the glued portion of the cathode if less than full utilization of zinc adjacent the sealed portions of the cathode is expected. This ring may be made of Volara® foam.

Referring to Fig. 7, an alternative method of mounting the cathode is to provide a casing of injection molded plastic with elements that pressure seal the cathode to the casing with a retaining ring. Instead of adhesive, the seals may be effected by means of a pressure-applying retaining ring and a resilient pressure-

sealant. The resilient pressure-sealant may be foam or rubber rings optionally coated with tar. Alternatively, the seals may be formed by epoxy as described above. The primer coating step may be skipped if the pressure induced by the retaining ring is sufficient to force adhesive into the porous material of the cathode.

5        The anode cover portion of the plastic cell, also of injection-molded plastic, has a groove or bead that mates with a groove or bead on cathode portion of the cell. The groove-bead combination retains the anode portion in place and provides a sealed trough channel into which an epoxy can be poured and retained. The latter bond is important to provide a strong seal around the casing that prevents leakage  
10 of electrolyte.

Before installation of the anode cover, a current collector, again, preferably of expanded metal screen, is connected through a feed through to the anode cover. This can be simply a rivet connecting the screen to an electrical contact. The zinc/electrolyte slurry is poured into the cathode portion of the cell casing and  
15 permitted to settle before installation of the anode cover. Epoxy 3M 2216 may be used to effect the final adhesion of the anode cover to the cathode portion of the casing. Instead of injection-molded plastic, the casing materials may be of vacuum-formed plastic such as Noryl®.

An alternative arrangement of cells is shown in Fig. 10. The cells are lined  
20 up with their primary planes perpendicular to the primary plane of the casing. Port holes are provided for air circulation as shown.

Battery packs are preferably supplied to consumers in specialized packaging that permits air to enter the packaging and supply the battery, but in very limited

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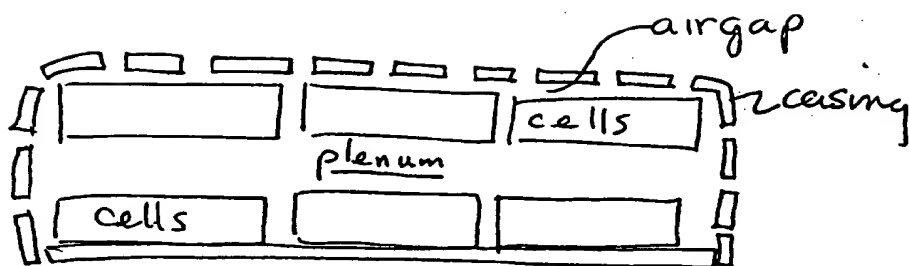
amounts. A preferred configuration is to provide an air-impermeable packaging structure, for example a blister pack, with a small laminated section perforated with a hole. The hole would be sized to insure that enough oxygen gets into the battery packaging that the battery has a usable voltage immediately prior to use. If the hole  
5 is too small, the battery will appear dead until enough oxygen diffuses into the cells to generate significant power. This can take minutes.

As described in patent application 09/201,524 entitled High Current Battery Power Supply, a high current, low stored-energy secondary battery may be used to make up for the metal-air battery's low peak current capacity. Referring to Fig. 9,  
10 in a preferred embodiment, the auxiliary battery may be formed directly into the casing of the battery using a lithium polymer battery because such battery cells may be formed into planar cells only 120 microns thick. Such battery technology is characterized by high pulse power as required by such implementations described in the '524 application identified above.

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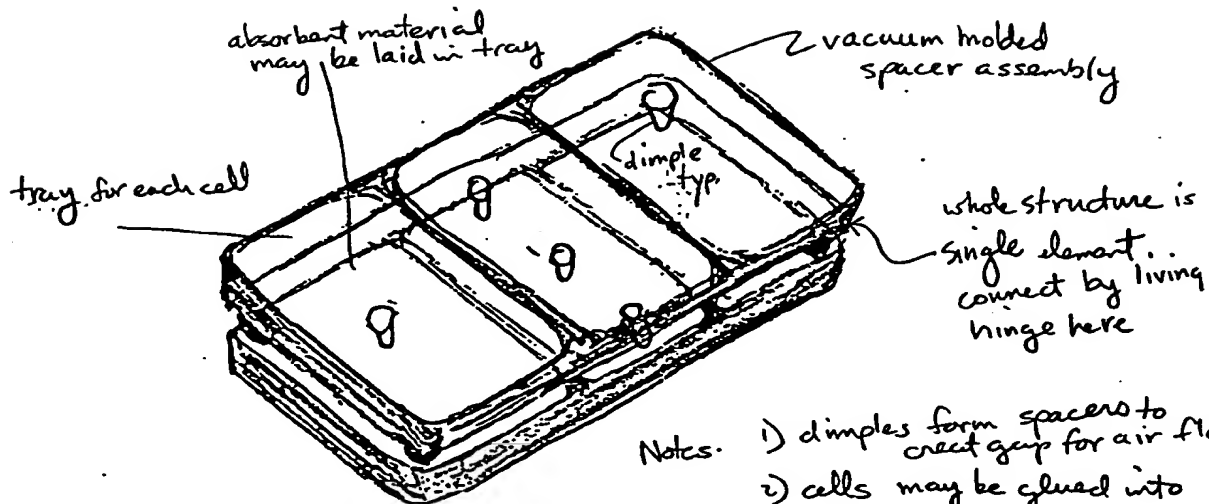


Fig. 1



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Fig. 2

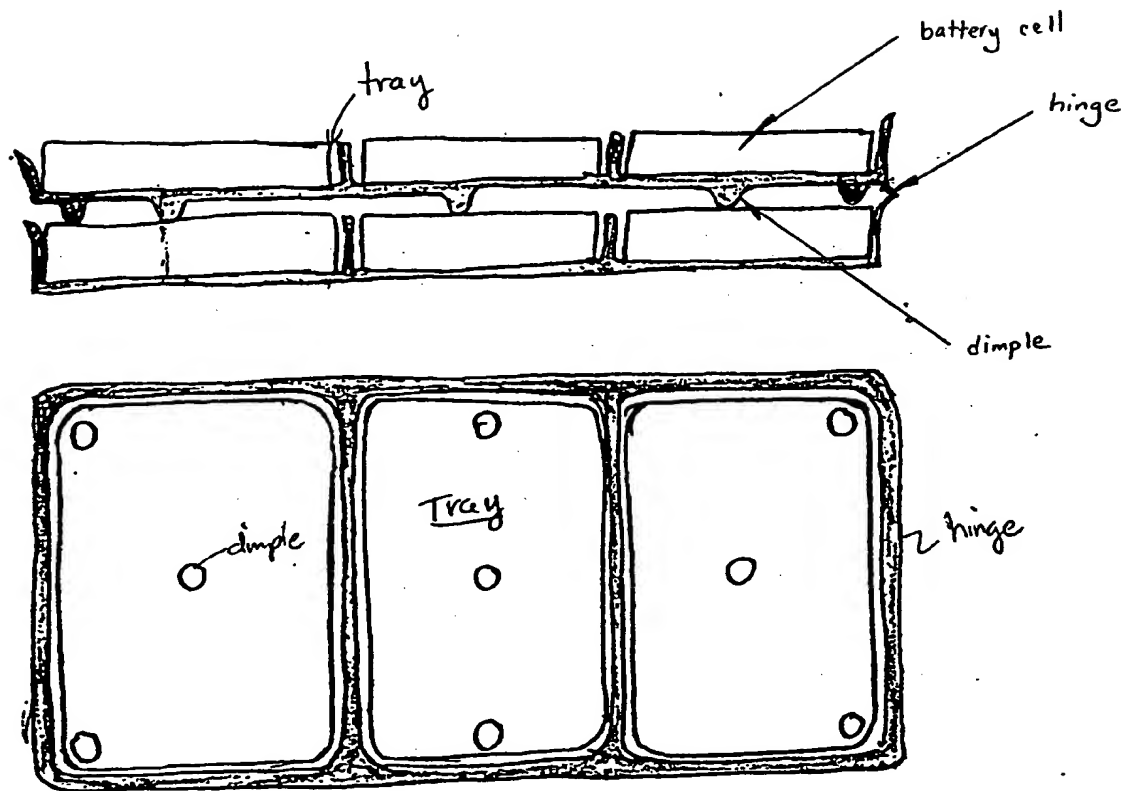


- Notes.
- 1) dimples form spacers to create gap for air flow
  - 2) cells may be glued into trays
  - 3) holes of cells face up ↑

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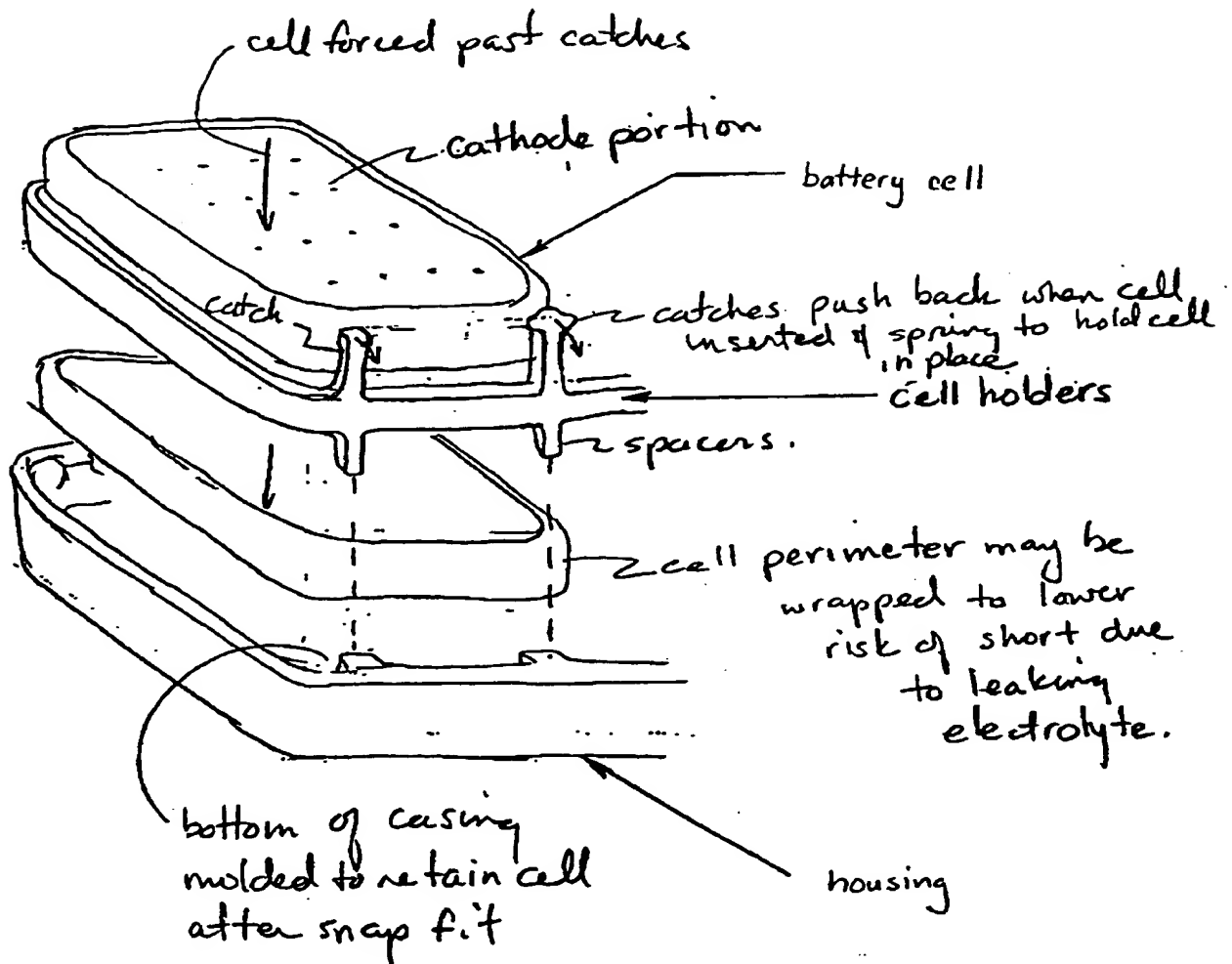
Fig. 2A

Same embodiment as Fig 2.



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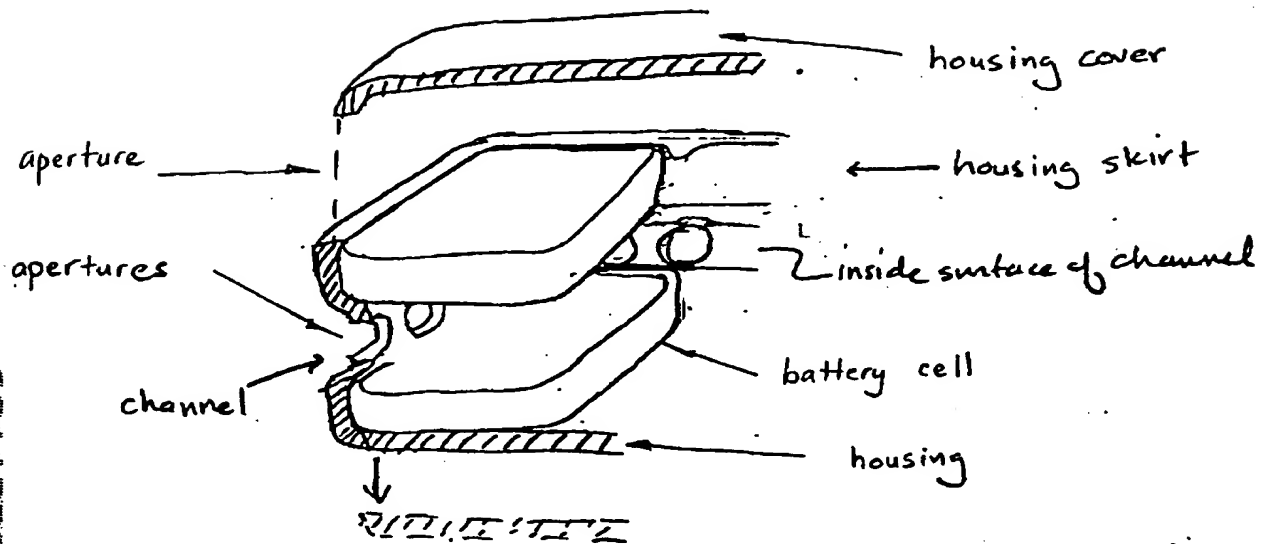
Fig. 3



Notes: housing cover is not shown. It attaches to bottom of casing

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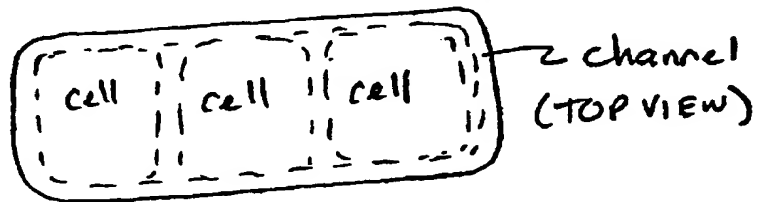
Fig. 4



Notes:

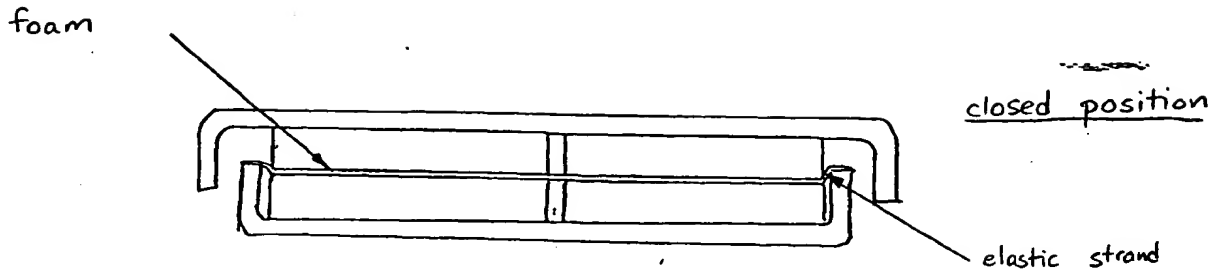
battery cells are snapped onto or glued onto housing and positioned such that air cathode holes face

the channel encircles the entire skirt

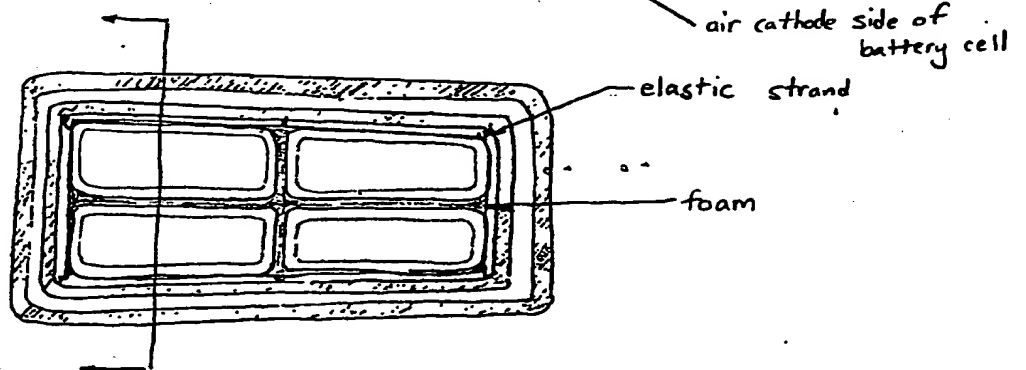
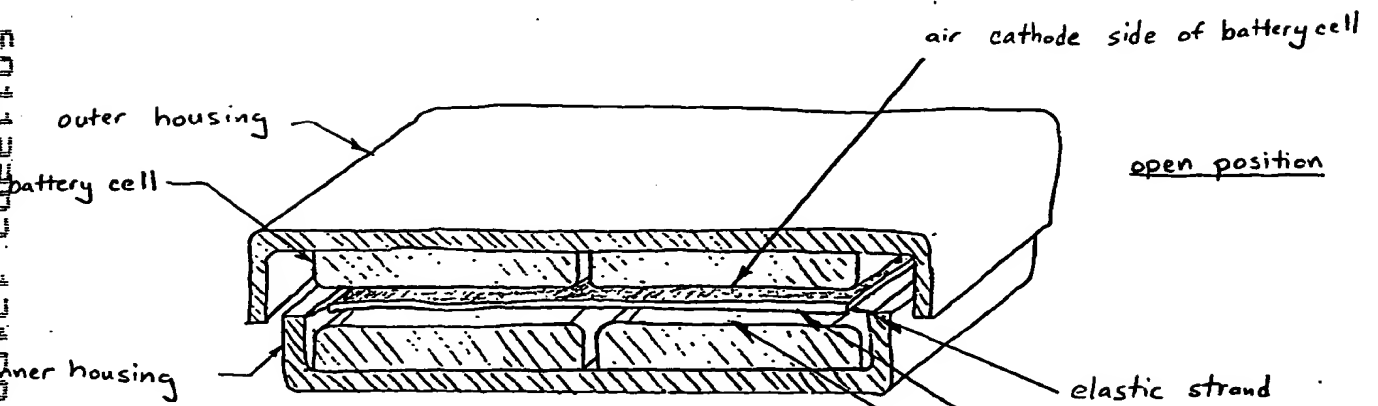


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Fig. 5

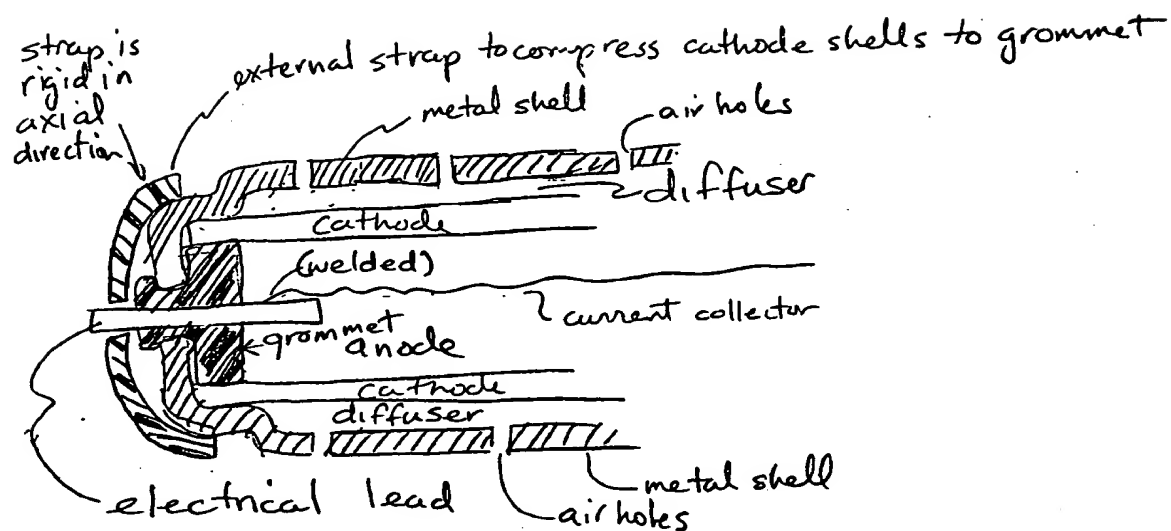


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- 1) when the battery is in the compact position, foam blocks substantially all of the air cathode holes
- 2) battery cells are glued to either the outer housing or the inner housing

Fig. 6



Notes: 1) the above structure may be glued together instead of compressed.

2) grommet is of resilient material in embodiment relying on compression for seal

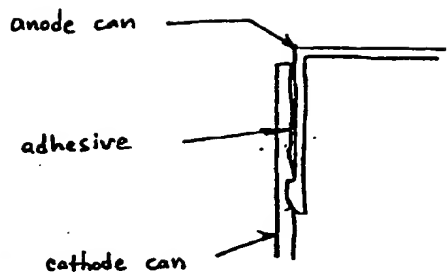
3) grommet may be rigid insulator if shells are glued to it.

4) electrical lead is molded into grommet or fitted and caulked to make seal.

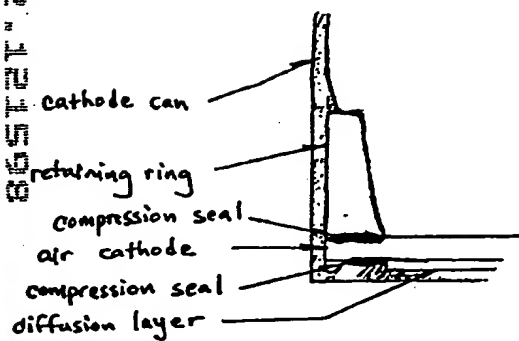
5) grommet may be of polysulfone

6) cathode electrical leads extend from shells.

Fig. 7



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battery cell

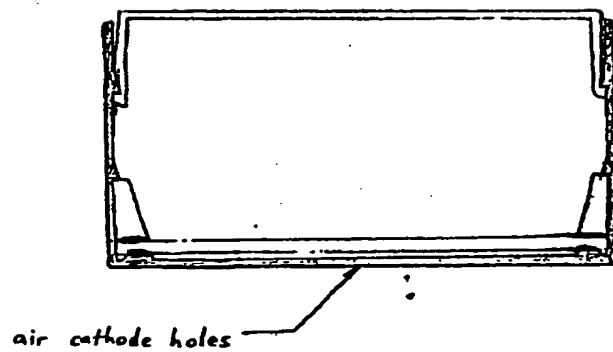




Fig. 8

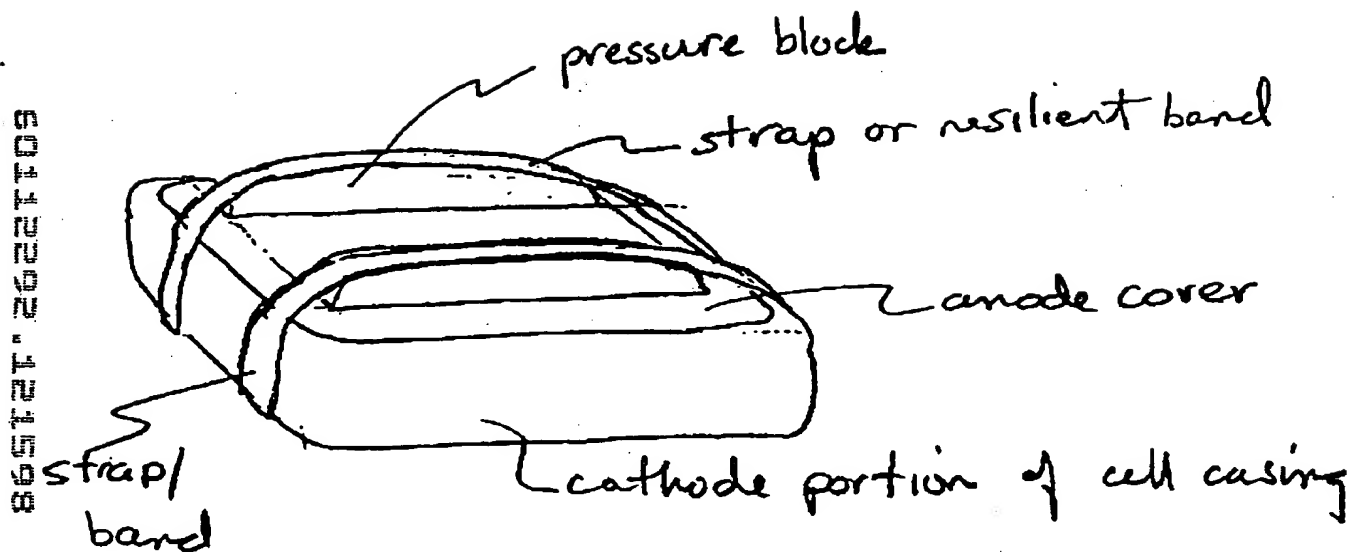


Fig. 9

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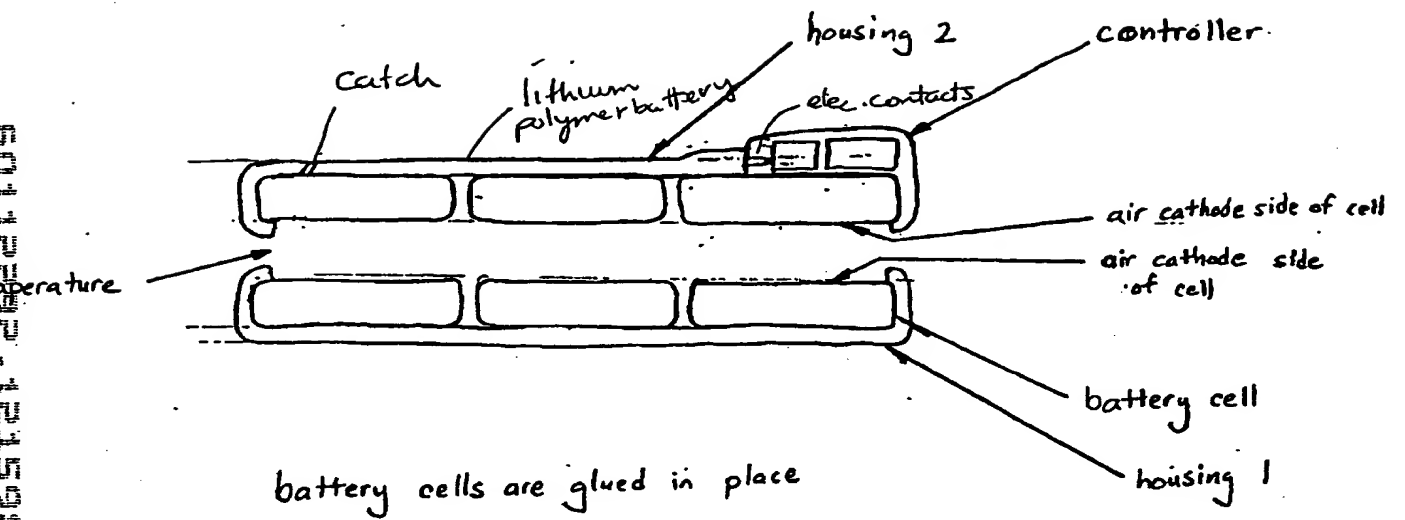
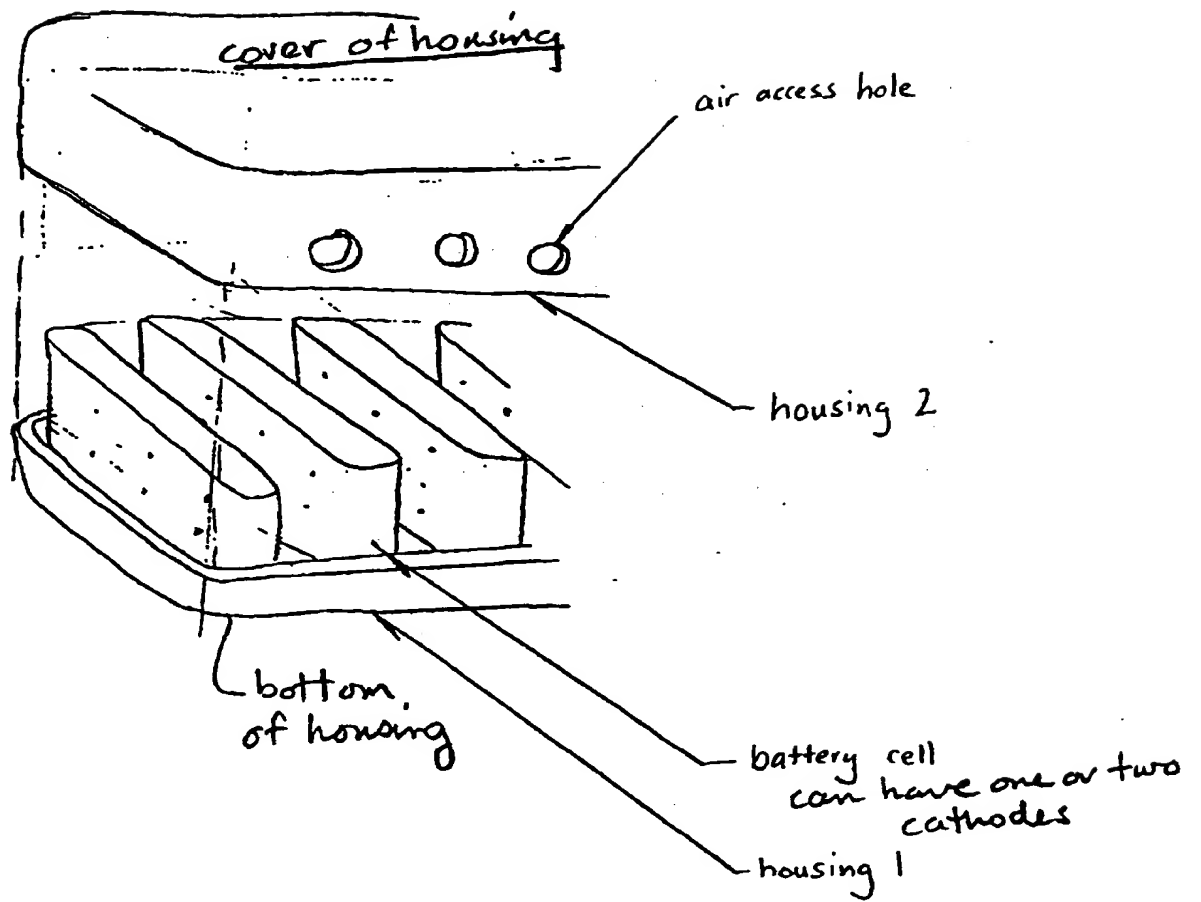


Fig. 9

Fig. 10



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